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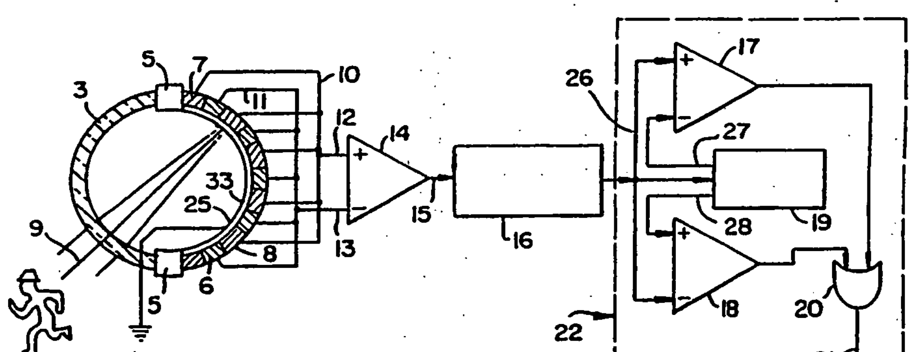

(57) Abstract

A miniature passive infrared motion detector contains an optical system, a pyroelectric polymer film and an electronic circuit. The optical system is made of a curved Fresnel lens (3) and an elongated wave guide having reflective inner surfaces (1, 4). This affords a very wide field of view by the optical system with the energy (9) of an intruder, for example, focused to a small point on the polymer film (8) which is also curved with the same radius as the lens (3) and has two interdigitized electrodes (6, 7) on the rear surface and one uniform electrode (33) on the front surface. The front electrode (33) is covered with infrared absorbent material. The electronic circuit contains a differential amplifier (14) and a threshold network (22).

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MOTION DETECTOR

BACKGROUND OF THE INVENTION

Any object emits radiation which spectral characteristics depend on the object's temperature. If temperature of the object is different than that of ambient, the radiation energy transfer occurs between the object and the surrounding space. This energy can be detected by an appropriate sensor. The moving warm object (like a human) not only radiates electromagnetic energy but its location with respect to the detector changes. The main power radiated by the humans is concentrated around the wave length of about 10 µm. In other words, the moving warm object can be differentiated from the surroundings by three factors: temperature, location and speed of moving. Therefore, the detection must consist of the following steps: collection of radiation, conversion of it into electrical signal and signal processing.

Several types of infrared detectors are known in the prior art. Mortensen (U.S. patent # 4,052,716) discloses a system with plurality of thermistors which collect radiation by means of a parabolic focusing mirror. It uses a capacitive coupling to distinguish between slow and fast moving objects. The similar detector utilizing a thermopile sensor is disclosed by Schwartz (U.S. pat.# 3,760,399 and Re. 29,082). In that invention, two fixed thresholds and OR gate are used to detect positive and negative going signals from the preamplifier. The location and direction of the moving object in the prior art is determined by the above cited authors and by Keller (U.S. pat. # 4,052,616) and Schwartz (U.S. pat # 3,958,118). All these detectors use either thermistors or thermocouples as discrete sensors.

The focusing systems in the prior art are made of lenses, parabolic mirrors and reflectors to concentrate radiation on the individual sensors. Some detectors use multiple Fresnel lenses (facet) which focus radiation on a single pyroelectric or thermopile sensor (RCA Motion Switch C-23, patent pending; Visonic Ltd. Motion Sensor SR-2000E; Kesser Electronics International, Inc. Infrared Sensor, Model 2006 and others presently commercially available). Instead of a small size solid-state sensor, a pyroelectric detector can be designed with a polymer film, such as polyvinylidene fluoride (PVDF). Cohen (U.S. pat.* 3,809,920) discloses a design which contains the polymer film with conductive electrodes on both surfaces. The heat flow from non-moving objects can be separated by the cancelling technique, as it was disclosed in the U.S. patent * 3,839,640 or by the use of a differential amplifier with common mode rejection of noise (Smith et al. U.S. pat. * 4,379,971). Smith's detector utilizes a polymer film with the interdigitized (alternating) electrodes on one side and a parabolic mirror as a focusing system. The patent of Southgate (U.S. pat.* 3,842,276) discloses the use of an alternative electrode arrangement on the opposite surfaces of the film to produce ambient temperature compensation.

SUMMARY OF THE INVENTION

In the preferred embodiment, the motion detector comprises of a shielding housing containing a pyroelectric polymer film having alternating (interdigitized) electrodes preferably on the rear surface and a uniform electrode on the front surface. The radiation is collected by the Fresnel lens made of a flexible infrared transparent material (polyethylene, e.g.). The lens is curved to the angle of the desired field

of view. The pyroelectric film strip is also curved with the same radius as the lens and positioned at the distance approximately equal to the lens' focal length. In other words, the lens and the film form a cylindrical surface with the lens and the sensing film on the opposite sides of the surface.

At the top and the bottom, the space of the cylinder is limited by two plates, inner surfaces of which preferably have to be reflective. This widens the field of view in a vertical plane. Since the pyroelectric film is located in a focal surface (the focal surface is cylindrical, because the lens is curved), a radiation from a distant object will be concentrated in a point. This concentrated energy will heat the film surface and the heat will propagate through the film thickness. This will result in generation of electrical charge due to the film's pyroelectricity.

Pyroelectric film is not responsive to constant temperature but rather to the change of the film temperature between the electrodes. Therefore, a stable thermal image on the film surface causes no output signal. When a warm (or cold) object moves, a thermal spot on the film surface also moves. In the proposed design, the pyroelectric film is located in the focal surface of the lens. The film has two conductive electrodes on both sides: uniform on the front and grid-like on the rear. The thermal point will cross the electrode grid when the object moves across the field of view. This, in turn, will cause an alternate electrical charge at the film electrodes, which then can be amplified and processed by the electronic circuit.

The electronic circuit consists of the preamplifier, amplifier, filter and a threshold circuit. A threshold may be either fixed or

floating. It also may be either single or bipolar, depending on the actual application of the detector.

The proposed method of bending both the lens and the sensor can be applied to the motion detector having a very wide field of view: up to 180° of solid angle. In this case, the lens and the film have to be formed into two hemi-spherical lunes facing each other. The sensor's hemi-sphere must also have an alternating sensitive surface, as in the cylindrical design. The electronic processing circuit is similar to that of the cylindrical sensor.

PVDF and other pyroelectrics exhibit also piezoelectric properties, which cause the sensor to become not only a heat detector, but a sound and vibration detector as well. Moreover, relatively fast changes in room temperature (because of the operation of heaters or air-conditioners, e.g.) may lead to false-positive detections. Most of these interferences can be considered as distributed over the surface of the sensor and can be cancelled as a common mode noise. Symmetrical interdigitized electrodes and a differential amplifier allow to dramatically improve signal-to-noise ratio providing low rate of false-positive detections.

SHORT DESCRIPTION OF DRAWINGS

FIG. 1 represents general layout of the preferred embodiment of the motion detector.

Fig. 2 shows a cylindrical detector block-diagram

Fig. 3 shows interdigitized rear electrodes

Fig. 4 is an equivalent circuit diagram of Fig. 3

Fig. 5 shows interdigitized electrodes on both sides of the film

Fig. 6 is an equivalent circuit diagram of Fig. 5

Fig. 7 is a timing diagram

Fig. 8 shows a sectional view of the detector

Fig. 9 shows a circular Fresnel Lens

Fig. 10 shows linear (cylindrical) Fresnel lens with multiple sections

Fig. 11 shows circular multiple sections Fresnel lens

Fig. 12 shows a spherical detector

Fig. 13 represents interdigitized rear electrodes for the spherical detector

Fig. 14 represents a multiple circular Fresnel lens for spherical detector

Fig. 15 shows a sectional diagram of cylindrical or spherical detector with multiple lenses.

DESCRIPTION

Fig. 1 shows a general arrangement of the preferred embodiment of the motion detector having cylindrical shape. The focusing lens, 3, and a pyroelectric film, 8, are positioned to shape a cylindrical surface in such a way as for the lens to be at the opposite side from the film. Upper, 1, and lower, 4, plates of the cylinder are made of a non -transparent material. These plates are connected through the side brackets, 5, which separate the lens, 3, from the film, 8. Cylinder diameter is approximately equal to the focal length of the lens, which forms its front side. The film, 8, has interdigitized (alternating) electrodes, 6 and 7, on its outer (rear) surface. In Fig. 1 film thickness

(which normally is in the range of 9 - 30 μ) is exaggerated for the better clarity. In Fig. 1 and 2 electrodes, 6 and 7, are conditionally marked with black and white colors and are isolated from each other. All "black" and all "white" electrodes are respectively connected, as shown by the networks, 10 and 11, in Fig. 2. The network, 10, is connected to the positive input, 12, of the differential amplifier, 14, while the network, 11, is connected to the negative input, 13. Inner (front) electrode, 33, of the film, 8, is grounded. The output of the differential amplifier, 14, is connected to the filtering and amplificating circuit, 16, which, in turn, is connected to the threshold circuit, 22. In the preferred embodiment, the threshold network consists of two voltage comparators, 17 and 18, which outputs are connected to the inputs of OR gate, 20. Threshold controller, 19, generates either constant or floating threshold voltages, 27 and 28. The floating voltages may be controlled by the output signals from the circuit, 16. The threshold circuit, 22, is of a conventional design and its operation is not described here in details.

The detector operates as follows. When a warm object (an intruder, e.g.) moves in the field of view (Fig. 2), a small part of its thermal energy, 9, is collected by the lens, 3, and focused into a warm spot, 22, on the surface of the film, 8. Since the film, 8, is totally located on the focal surface of the lens, 3, the energy will be always focused into a small spot regardless where in the field of view an object is located. When the object moves, the warm spot, 22, also moves along the film, crossing its electrode borders. Since adjacent electrode "fingers" are connected to the opposite inputs of the differential amplifier, 14, an output voltage, 15, is changing. These changes are filtered by the filtering circuit, 16, which, in general, is a band-pass

filter, having cut-off frequencies of about 0.2 - 5 Hz. After further amplification by the circuit, 16, the signal, 26, goes to the threshold network, 22, where it is compared with two thresholds: positive, 27, and negative, 28, as it is shown in Fig. 7. Two thresholds permit to detect both polarities of the signal, doubling detector's resolution. Output voltages from the comparators are square pulses which are combined in the OR gate, 20. Its output pulses, 21, (Fig. 7) are the output signals of the motion detector.

Most of the possible interferences can be considered as common mode signals with respect to the pyroelectric film surface. Therefore, the sensitive area of the film, 8, is divided into two approximately equal areas (Fig. 3) which are connected to the inverting and non -inverting inputs of the differential amplifier, 14, as it is shown in the equivalent circuit diagram of Fig. 4. This results in cancellation of common mode interferences, such as acoustic noise, vibration, changes in the ambient temperature, changes in the illuminating conditions, etc. The other side of the film, 8, has a uniform electrode, 33, which shall be grounded.

In the alternative design, both sides of the film, 8, may be covered with interdigitized electrodes as it is shown in Fig. 5 and equivalent circuit of Fig. 6. The front electrode, 34, is connected to the rear electrode, 6, and grounded and the front electrode, 35, is connected to the rear electrode, 7, and to the non-symmetrical amplifier, 36. In this case, common mode rejection is performed by the alternating pairs of electrodes and a simpler unipolar amplifier can be used.

It is follows from the above description, that the cylindrical detector has a very wide angle of view in the horizontal plane. Although, an angle in a vertical plane is quite narrow. To increase the vertical angle, the inner surfaces, 23 and 24, of the top and bottom plates, 1 and 4, have to be made highly reflective (Fig. 8). In this case, radiation beam, 9, coming from a wider angle, will bounce from the mirror-like surface, 24, and reach the film, 8. Obviously, if no wide angle is desired, the surfaces, 24 and 23, must be not reflective or covered with heat absorbing coating (flat black paint, e.g.).

There is a variety of Fresnel lenses which can be used in the cylindrical detector. Fig. 9 shows a circular lens, while Fig. 10 represents a cylindrical Fresnel lens, divided into several sections, A, B and C. This sectioning may be desirable to improve performance of the Fresnel lens which is curved. A circular lens also may be used in a multiple sections, A, B and C as it is shown in Fig. 11.

An alternative way to make a wide angle of view in both vertical and horizontal planes is shown in Fig. 12. Both the lens, 30, and the sensing film, 29, are formed into hemi-spherical lunes, facing each other. The functionality of the spherical sensor is generally the same as of the cylindrical sensor as described above. Spherical sensor can accept signals from any direction, 31 or 32, practically within a solid angle of almost 180°. Rear surface of the sensor, 29, must also have alternating electrodes. Many shapes of the electrodes are possible, like checker-board pattern shown in Fig. 12 or circular pattern, shown in Fig. 13. Alternating electrodes are conditionally shown in Figs. 6 and 7 in the white and black colors. The hemi-spherical lenses also can be constructed in a multiple-section fashion, as it is shown in Fig. 14. The multiple sections, A, B and C serve their individual sections of the

pyroelectric film, 8 (Fig. 15). For instance, section C of lens, 3, creates images in the section C' of the film, 8. Since each section is curved with a relatively small angle, its spherical aberration will cause little distortion of a warm spot on the film surface. This will result in better resolution and extended operating distance of the motion detector.

WHAT I CLAIM IS:

1. A passive radiation motion detector which is capable of sensing thermally radiated energy from a moving object, comprising:

a flexible sheet of pyroelectric material which will generate an electrical charge in response to a change in its surface temperature, formed in a curvature surface;

at least one area of electrically conductive layer forming at least one first electrode and covering one surface of the said pyroelectric material;

at least one area of electrically conductive layer forming at least one second electrode arranged on the opposite side of said pyroelectric material from said first electrode;

a focusing lens formed in a curvature and positioned at the opposite side from the said sheet of pyroelectric material;

electrical conductors connected to the said electrodes;

an electronic circuit for amplification and processing of electrical signals received via said conductors.

2. A passive radiation motion detector as defined in claim 1 wherein said second electrode is formed of two approximately equal areas of electrically conductive material being connected to a compensating means capable of rejecting common mode signals from said areas of the said second electrode.

3. A passive radiation motion detector as defined in claim 2, wherein said areas of electrically conductive material are divided into smaller interconnected sections and the sections of the respective

areas arranged in alternating fashion on the surface of said pyroelectric material;

4. A passive radiation motion detector as defined in claim 1 wherein a thin layer of thermally absorbing material adhered to at least a portion of one of said electrodes.

5. A passive radiation motion detector as defined in claim 1 wherein said first electrode is electrically connected to ground to provide electrostatic shielding.

6. A passive radiation motion detector as defined in claim 1 wherein said first electrode is divided into two approximately equal areas of electrically conductive material and one of these areas is electrically connected to said electronic circuit while the other area is electrically connected to ground.

7. A passive radiation motion detector as defined in claim 1 wherein said flexible sheet of pyroelectric material is made of polyvinylidene fluoride.

8. A passive radiation motion detector as defined in claim 1 wherein said focusing lens is Fresnel lens.

9. A passive radiation motion detector as defined in claim 1 wherein said focusing lens is curved to form cylindrical surface.

10. A passive radiation motion detector as defined in claim 9 wherein said lens is curved with radius approximately equal to its focal length.

11. A passive radiation motion detector as defined in claim 1 wherein said lens made of polyethylene.

12. A passive radiation motion detector as defined in claim 1 wherein said lens is divided into sections and each section is made of individual Fresnel lens.

13. A passive radiation motion detector as defined in claim 1 wherein said lens formed into part of spherical surface.

14. A passive radiation motion detector as defined in claim 1 wherein said pyroelectric material formed into part of spherical surface.

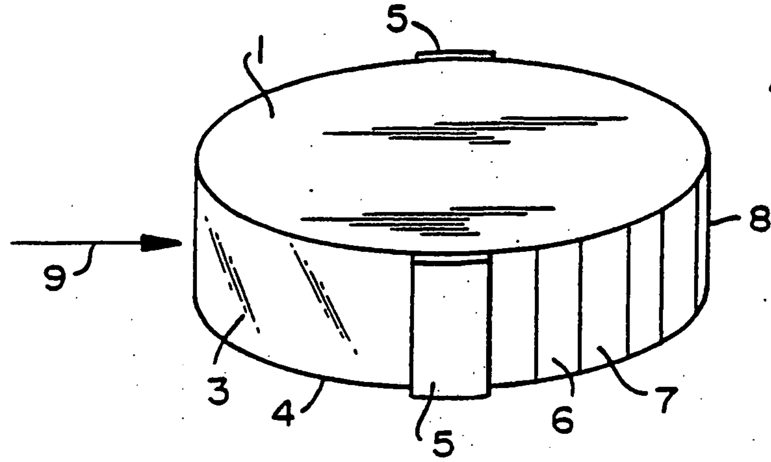


FIG. 1

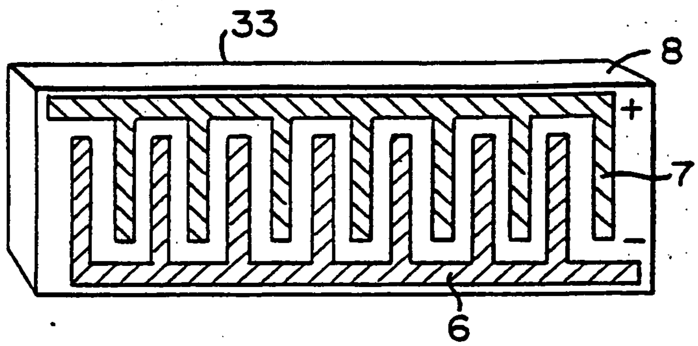


FIG. 3

FIG. 4

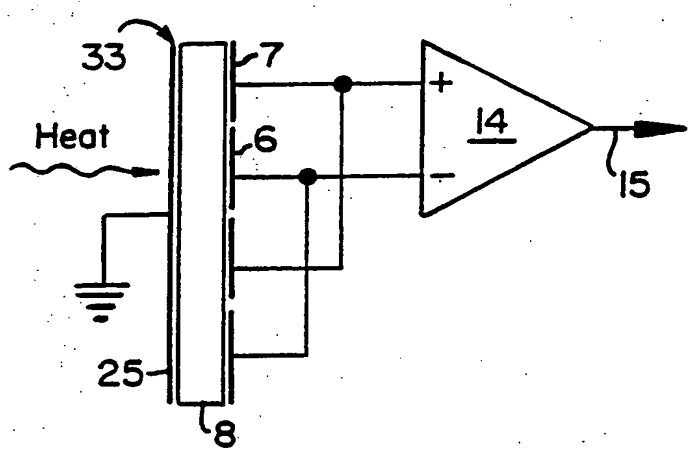
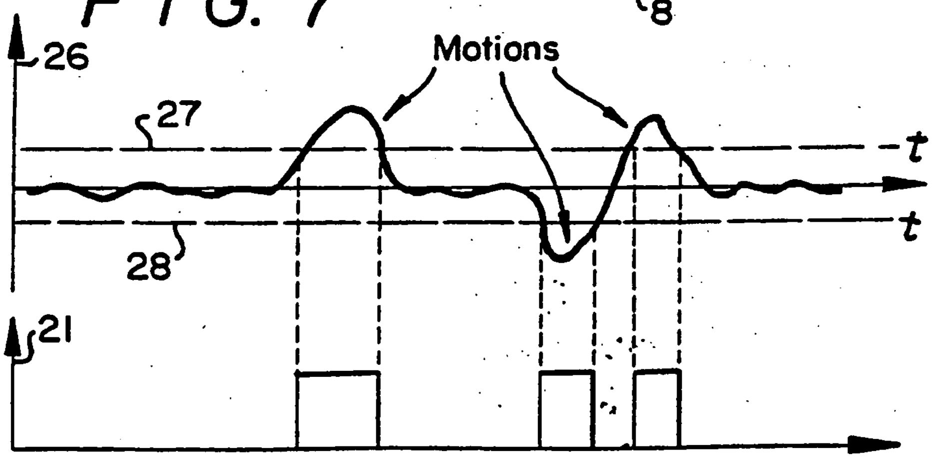


FIG. 7



SUBSTITUTE SHEET

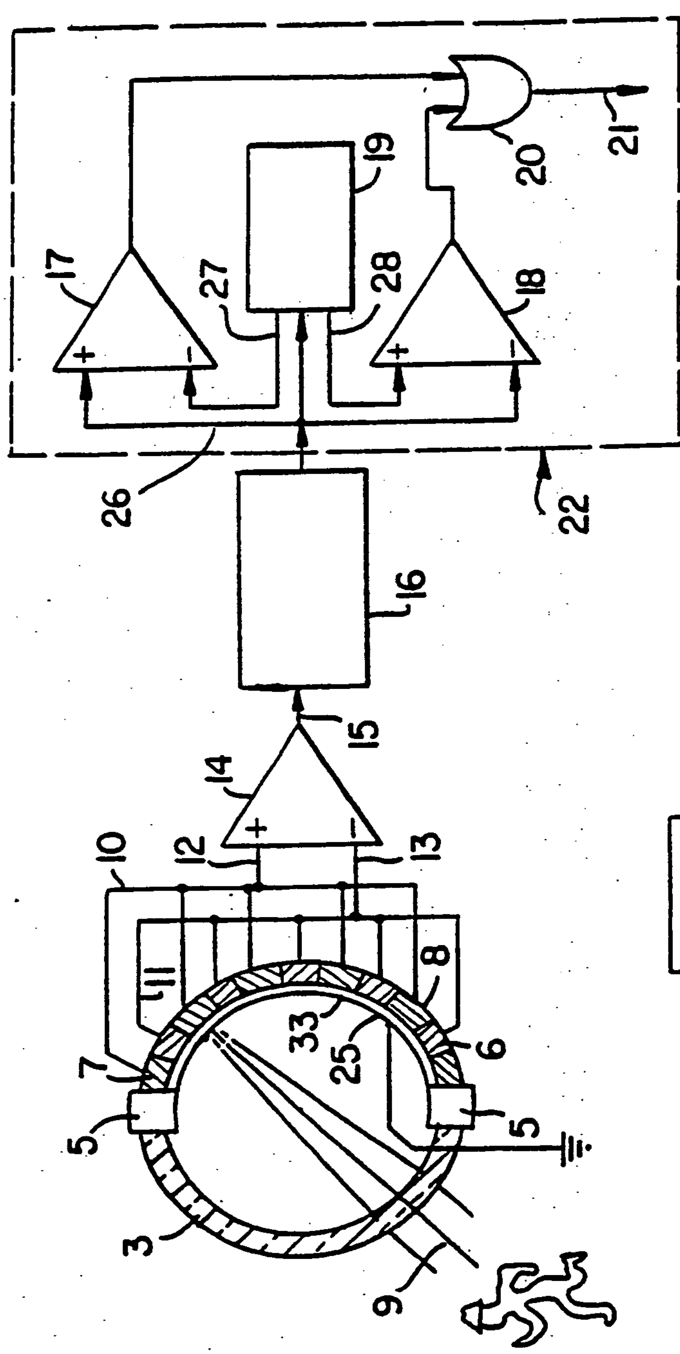


FIG. 2

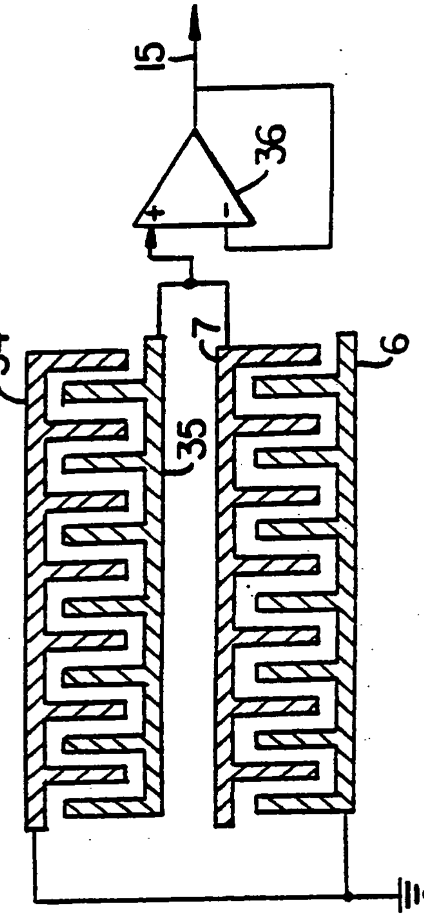


FIG. 5

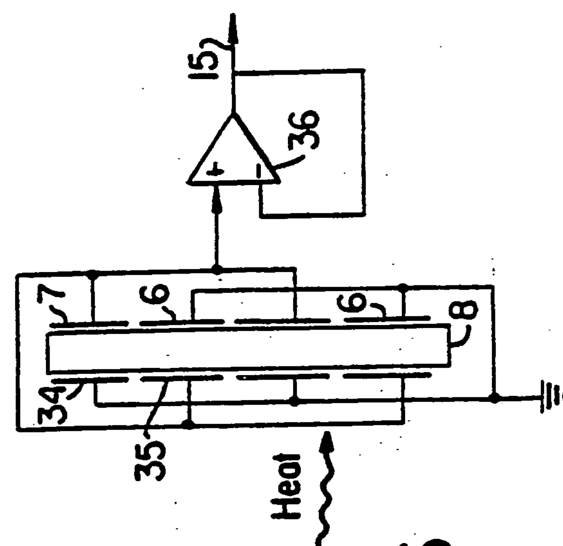


FIG. 6

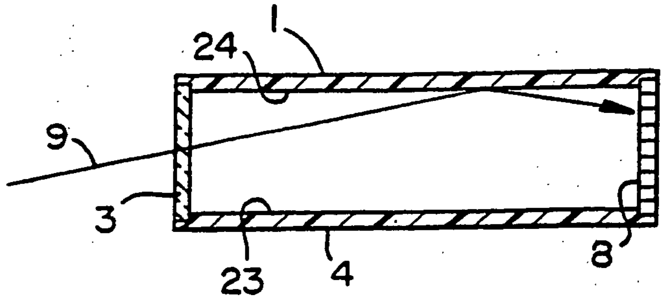
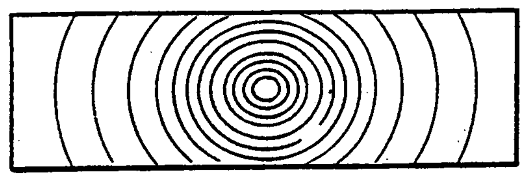


FIG. 8

FIG. 9



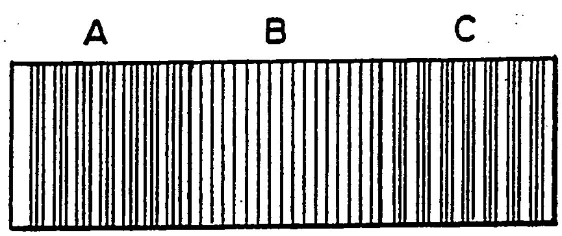


FIG. 10

FIG. 11

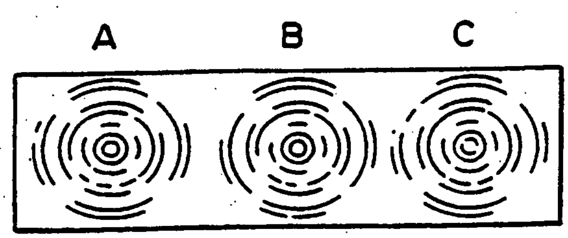
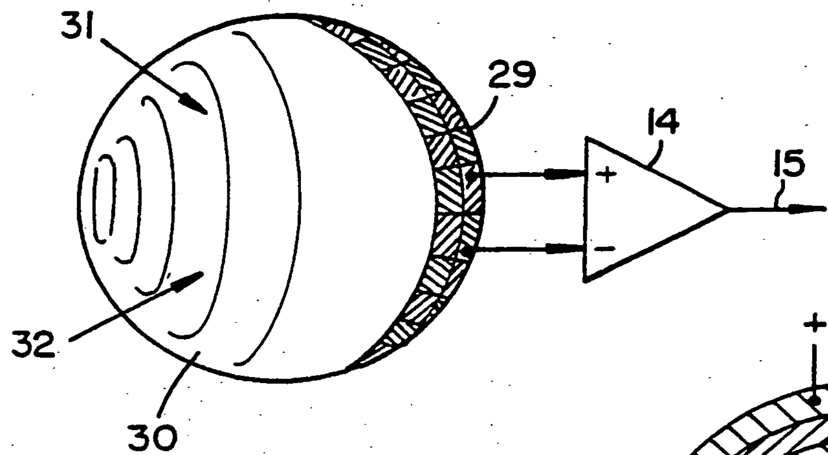


FIG. 12



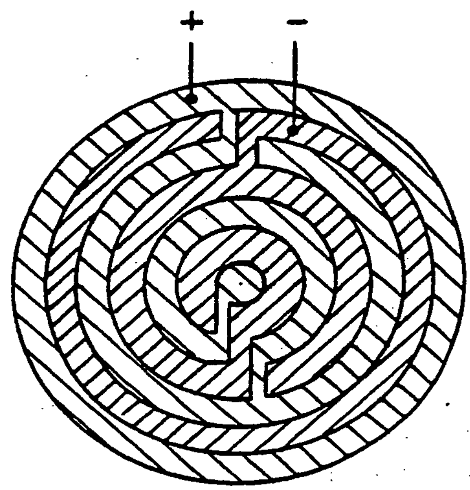


FIG. 13

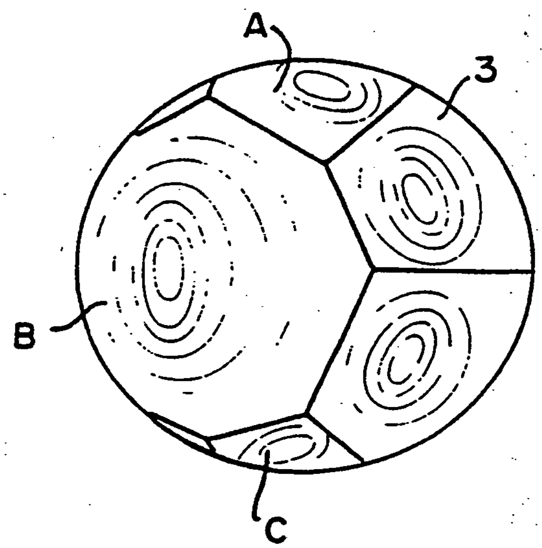


FIG. 14

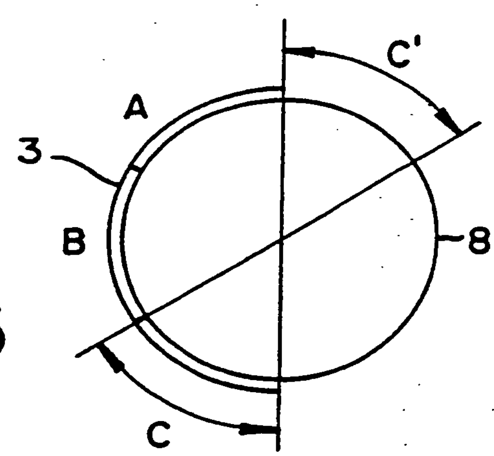


FIG. 15

INTERNATIONAL SEARCH REPORT

International Application No PCT/US87/03037

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4] : G01J 5/08 U. S. Cl. : 250/342

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U.S.	250/338 PY, 342, 353 340/567, 600

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A, 3,760,399 (SCHWARZ) 18 SEPTEMBER 1973 (22.09.73).)	1-14
A	US, A, 3,809,920 (COHEN *ET AL.*) 07 MAY 1974 (07.05.74).)	1-14
A	US, A, 3,839,640 (ROSSIN) 01 OCTOBER 1974 (01.10.74).)	1-14
A	US, A, 3,842,276 (SOUTHGATE) 15 OCTOBER 1974 (15.10.74).)	1-14
A	US, A, 3,958,118 (SCHWARZ) 18 MAY 1976 (18.05.76).)	1-14
A	US, E, Re.29,082 (SCHWARZ) 14 DECEMBER 1976 (14.12.76).)	1-14
A	US, A, 4,052,616 (KELLER) 04 OCTOBER 1977 (04.10.77).)	1-14
A	US, A, 4,052,716 (MORTENSEN) 04 OCTOBER 1977 (04.10.77).)	1-14
Y	US, A, 4,225,786 (PERLMAN) 30 SEPTEMBER 1980 (30.09.80) figures 1-4.)	1-3, 5-14
Y	US, A, 4,321,594 (GALVIN *ET AL.*) 23 MARCH 1982 (23.03.82) figure 5, column 3, lines 13-20.)	1-3, 5-14
A	US, A, 4,379,971 (SMITH *ET AL.*) 12 APRIL 1983 (12.04.83).)	1-14

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
16 FEBRUARY 1988	18 MAR 1988
International Searching Authority [1]	**Signature of Authorized Officer** [20]
ISA/US	CONSTANTINE HANNAHER Constantine Hannaher

FURTHER INFORMATION C NTINUED FROM THE SECOND SHEET

Y	Applied Optics, Volume 13, no. 5, issued 1974 May (US) W. R. Blevin and Jon Geist, 'Influence of Black Coatings on Pyroelectric Detectors', see page 1177 esp. "Conclusions".)	4

V.☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE 10

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1.☐ Claim numbers ...., because they relate to subject matter 12 not required to be searched by this Authority, namely:

2.☐ Claim numbers ...., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out 13, specifically:

VI.☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING 11

This International Searching Authority found multiple inventions in this international application as follows:

1.☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2.☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3.☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4.☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.